DROUGHT RELIEVING RAINS FOR ATLANTIC COASTAL STATES, AUGUST 23–26, 1957

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1. INTRODUCTION

The summer months of 1957 have been among the driest on record at many eastern United States stations. Atlantic City, N. J., Philadelphia, Pa., Washington, D. C., Greenville, S. C., and Chattanooga, Tenn., all experienced the driest July on record [1]. Rainfall deficiency persisted through much of August with sporadic showers giving only temporary relief to small areas.

The serious nature of the drought is illustrated by this comment from the *Weekly Weather and Crop Bulletin, National Summary*, for the week ending August 19, 1957 [1]: "Prolonged drought tightened its grip over most of [the] area [Maryland and Delaware] during the week. . . . Field and sweet corn in the two-State region and about one-half of [the] southern Maryland tobacco crop [were] too far advanced to be benefited [from subsequent rain]."

This article will examine the events leading up to frontal wave development along the Carolina coast and the subsequent rainfall in amounts large and general enough to relieve the drought of the Atlantic Coastal Plain States.

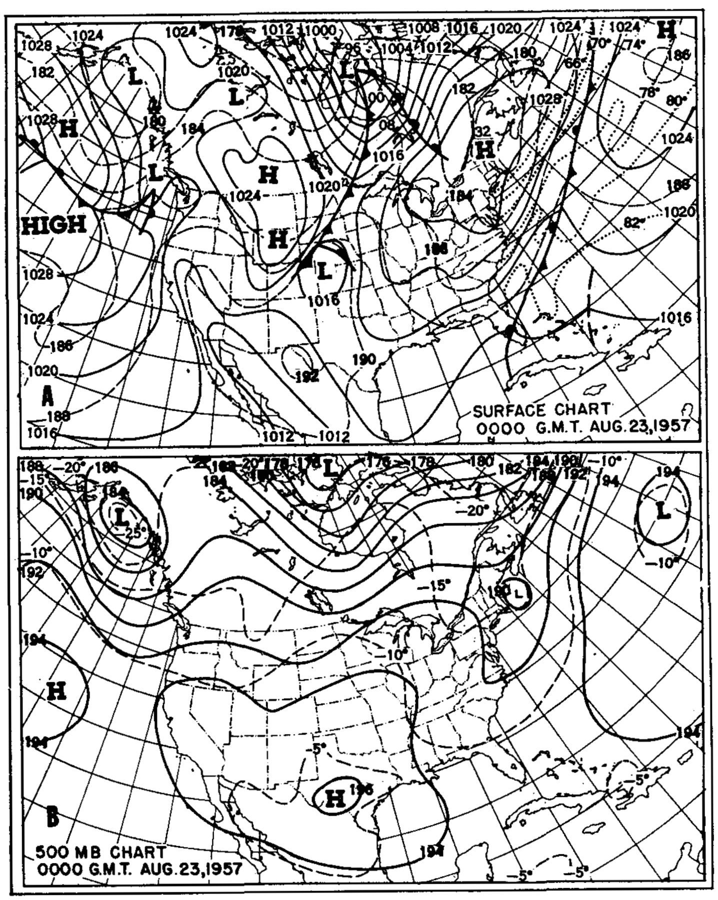

FIGURE 1.—Synoptic patterns for 0000 GMT, August 23, 1957. (A) Surface isobars (solid lines) with fronts, and 1000–500-mb. thickness lines (dashed). Stippled area shows current precipitation pertinent to this study. Dotted lines along east coast are mean sea surface isotherms. (B) 500-mb. chart with height contours (solid lines) and isotherms (dashed lines).

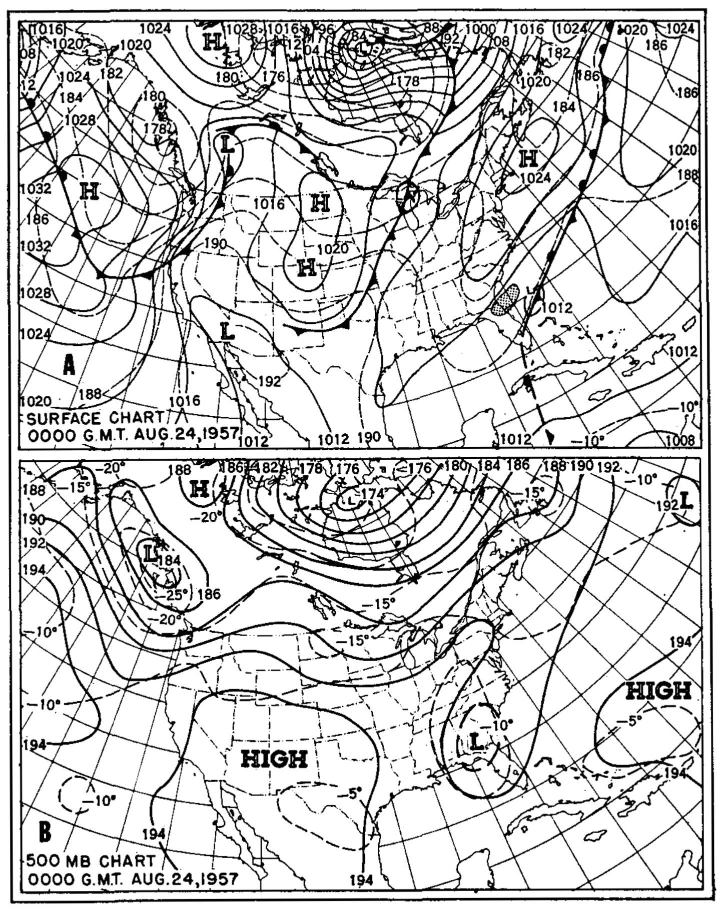

FIGURE 2.—Synoptic patterns for 0000 GMT, August 24, 1957.

2. ANTECEDENT CONDITIONS

The long-wave pattern of the 500-mb. level at 35° N. during much of the summer of 1957 was so organized as to maintain troughs near 75° W. and 130° W. with a ridge near 90° W. North of 45° N. the pattern was more changeable. As the storms' centers passed through Canada, the associated fronts affected the northern tier of States and little impression was made on the pattern over the South and Southeast. See article by Green [2] elsewhere in this issue for more comprehensive discussion of the month's weather.

During mid-August, a cold front of moderate intensity passed off the east coast, the cold air penetrated deep into the southeastern States, and completely dominated the entire area east of the Mississippi River (fig. 1A). Subsequent wave development on the front near Charleston, S. C., brought the relief from drought conditions.

3. SYNOPTIC ASPECTS

The passage of the cold front along the east coast was followed by the season's first large (1034 mb.) "cold" High, pictured in figure 1A, 0000 GMT, August 23. The 500-mb. chart for the same time (fig. 1B) illustrates the upper-air picture prior to frontal wave development. The main features were cold troughs along the east coast and just off the west coast with a less evident long-wave ridge between them. The trough along the western border of the Dakotas became increasingly important as it moved through the long-wave ridge in central United States. The small amplitude of this trough is characteristic of short-wave troughs as they move through long-wave ridge positions with their significance frequently being masked until they emerge east of the major ridge position. A good indicator of the trough's potential was shown in the 12-hour 500-mb. height fall pattern that preceded it and which brought a complete collapse, with time, of the ridge extending into northeastern United States. A deepening Low at 500 mb. over Hudson Bay was associated with surface development in that same area.

By 0000 GMT, August 24 (fig. 2A), there was evidence of squally weather and a tightening pressure gradient in the area east of Jacksonville, Fla. A closed low circulation was analyzed on the surface chart. The easterly wave shown in figure 1A merged with the frontal trough, and, perhaps, aided in the surface development. At 500 mb. (fig. 2B), the ridge over Pennsylvania had become quite narrow. The resultant flows favored the east-southeastward advection of both the cold air and vorticity in the Great Lakes trough. In view of this expected pattern, development was forecast by NAWAC, working from 0600 GMT, August 24 data, to occur on the east coast frontal system. The intensity of this development was correctly forecast, but it was positioned too far east.

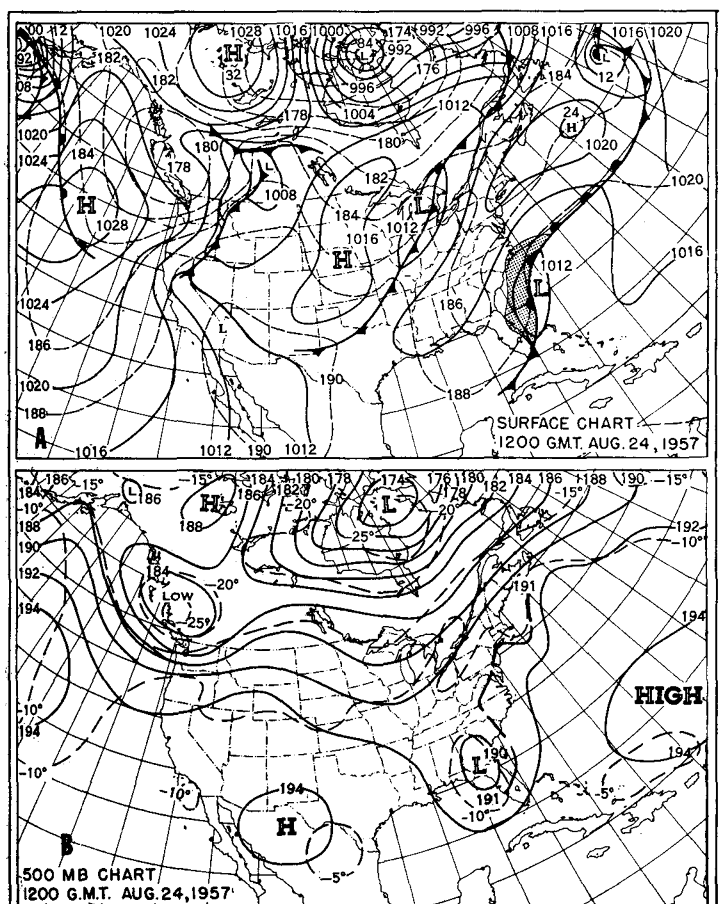

FIGURE 3.—Synoptic patterns for 1200 GMT, August 24, 1957.

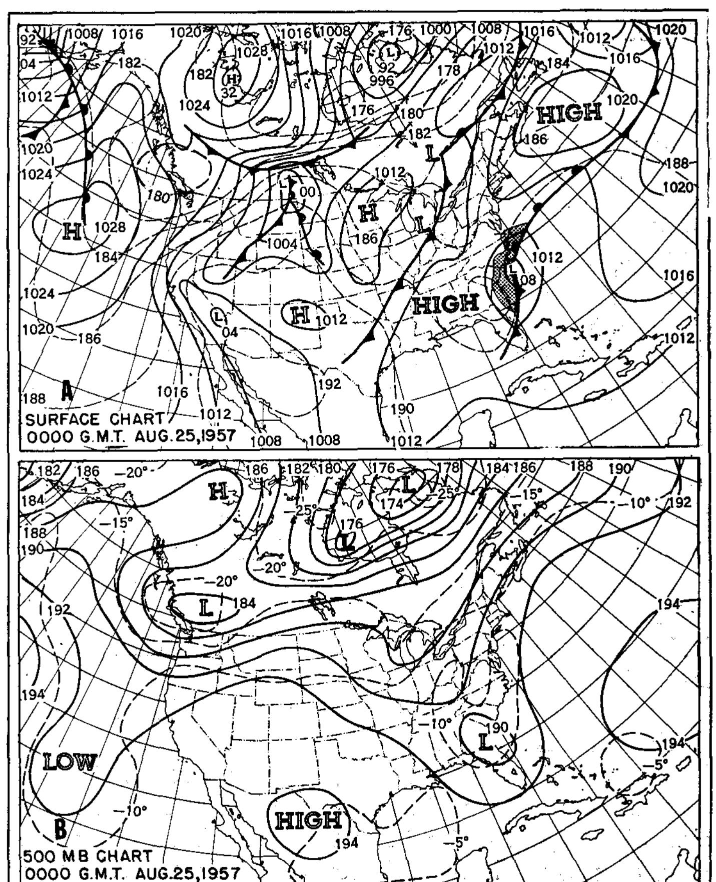

FIGURE 4.—Synoptic patterns for 0000 GMT, August 25, 1957.

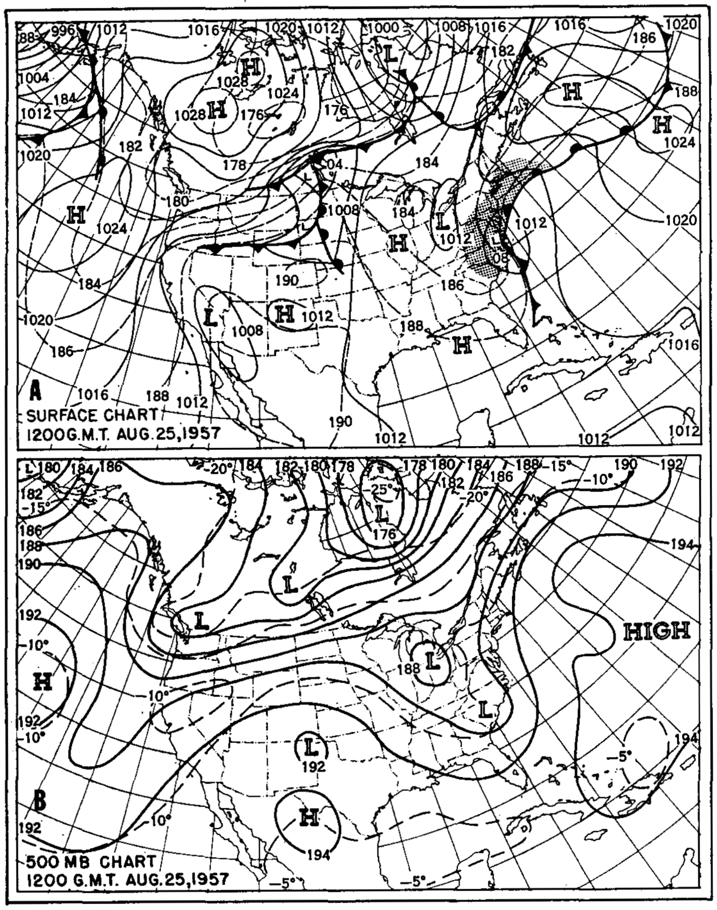

FIGURE 5.—Synoptic patterns for 1200 GMT, August 25, 1957.

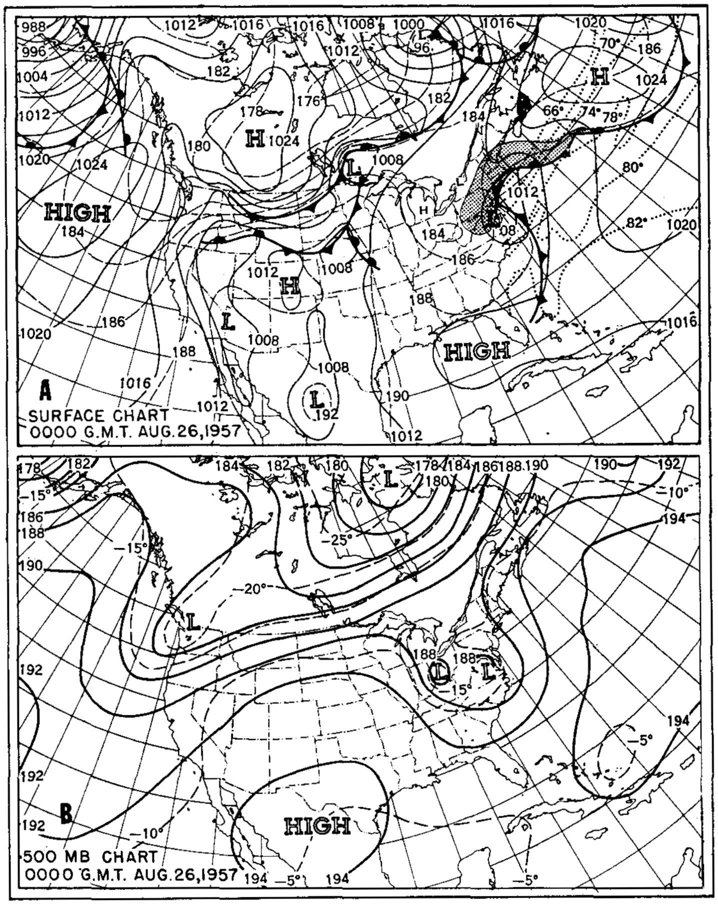

FIGURE 6.—Synoptic patterns for 0000 GMT, August 26, 1957.

By 1200 GMT, August 24 (fig. 3A), the wave in the vicinity of Charleston, S. C., had begun to develop and to move north. The surface High moved rapidly eastward, opening the path for a coastal track. The new surge of cold air, with cold front through the Great Lakes area, was becoming difficult to separate and delineate from the air over the east coast. In spite of a well defined pressure trough through the Great Lakes region, the 1000–500-mb. thickness lines indicated a weakening thermal pattern and the front was classified as cold, weak, decreasing. The deepening over Hudson Bay had ceased and a break-off Low moved out into the Atlantic. At 500 mb. (fig. 3B) the Low over Georgia had been forced south as the trough deepened over the Great Lakes. Winds over the Carolinas that had been east were now south and precipitation had begun at Hatteras, Wilmington, and Cherry Point, N. C. This overrunning along the front was an indication of increased development.

By 1800 GMT, August 24 precipitation had spread north to the Norfolk, Va., area, with a tongue of moderate to heavy precipitation extending west and south into the southwestern corner of North Carolina. Maximum precipitation reported for the 24-hour period ending 1200 GMT, August 25 during this period of storm development was 2.96 in. at Chapel Hill, N. C.

By 0000 GMT, August 25 (fig. 4A) the surface ridge over New England had weakened further as the pressure falls from the Lake Region moved into the general trough area along the east coast. Deepening was indicated by the increase in area enclosed by the 1012-mb. isobar, as the analyzed central pressure fell from 1010 mb. to 1006 mb.

The 500-mb. Low at the same time (fig. 4B) had begun to turn east and north to follow the surface system northeastward along the coast. Flow over the Chesapeake Bay area at the surface was light east to northeast while that at 500 mb. was moderate south-southwest, an indication of substantial overrunning. Active precipitation was reported at Atlantic City, N. J., Chincoteague and Norfolk, Va., and extending south around the low to Elizabeth City and Wilmington, N. C., and Myrtle Beach and Charleston, S. C. As the Low developed, so did the area of precipitation.

By 1200 GMT, August 25 (fig. 5) the cold front in the Ohio Valley had frontolyzed; there was no thermal definition remaining in the 1000–500-mb. thickness field nor in the surface temperature field. There was, however, still a surface and 500-mb. Low over Lake Erie.

The cold air and cyclonic vorticity with these Lows were now ideally situated to move into the long-wave east coast trough and assist in the retrogression that was necessary to permit the Low to remain near the coast.

Since its formation east of Jacksonville, the east coast

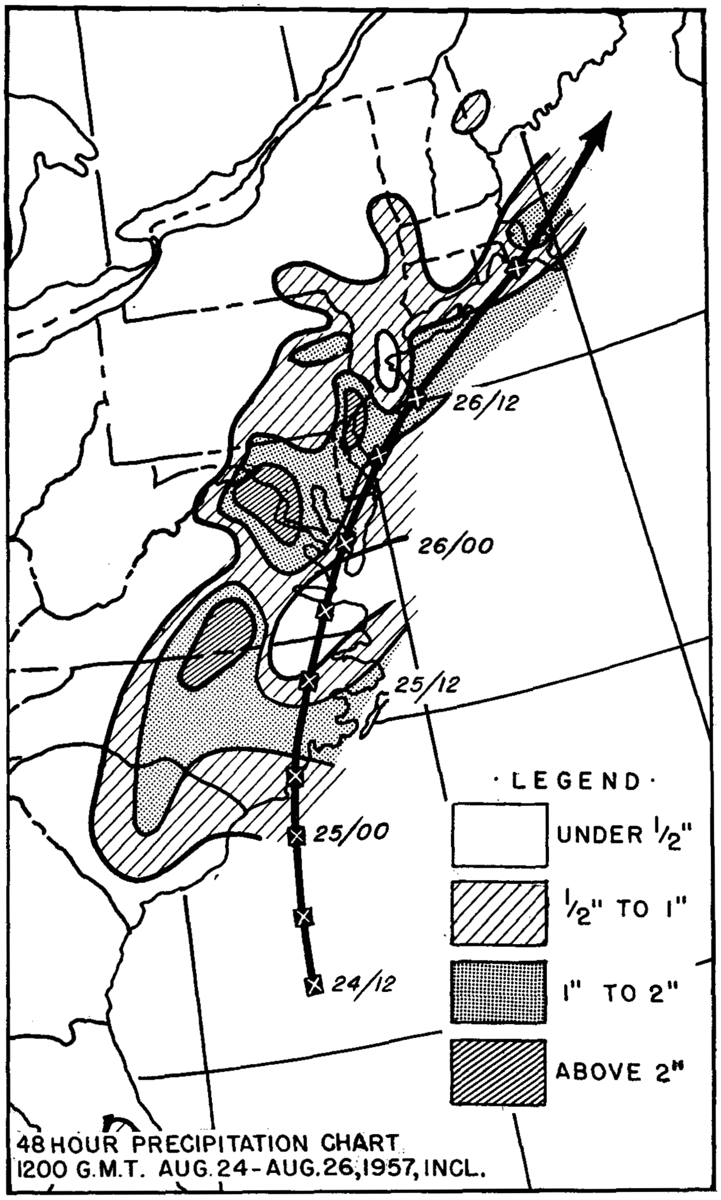

Figure 7.—Precipitation pattern showing total accumulation for 48-hour period 1200 GMT, August 24 to 1200 GMT, August 26, 1957. ⊠ indicates track of surface Low at 6-hour intervals.

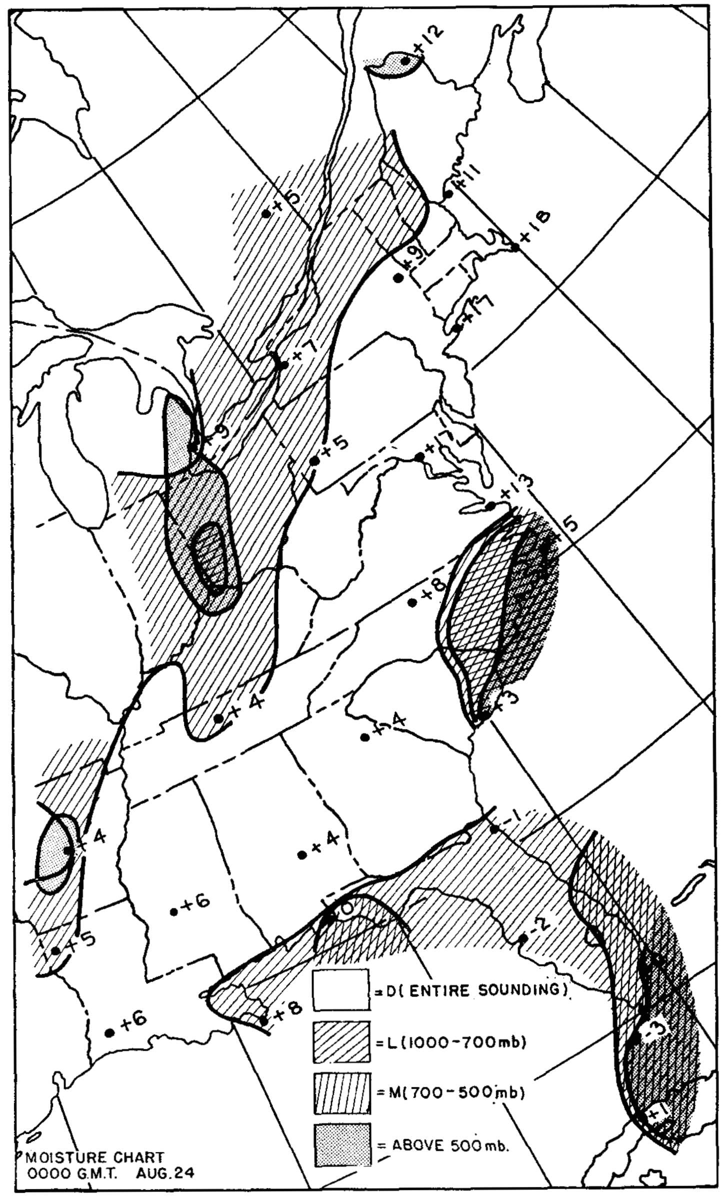

Figure 8.—Moisture chart for 0000 GMT, August 24, 1957. Dew-point depression is indicated by shading and keyed by letter. L=≤4°C. for layer between 1000 and 700 mb., M=≤6° C. for layer between 700 and 500 mb., H=≤8° C. for layer above 500 mb., and D=no single layer meets above criteria. Stability indices are also shown.

Low had moved north with a speed of about 12 knots. Direction and speed were uniform until 0000 GMT, August 26, when the Low was over lower Del-Mar-Va Peninsula. Coincident with its arrival over that area, winds aloft along the coast from Delaware northward had backed to southerly and had increased from 15 knots to 40 knots. Subsequent to 0000 GMT, August 26, forward motion of the storm increased to 15, to 18, to 22 knots, during each successive 6-hour period (averaged over 12-hour period).

By 0000 GMT, August 26 (fig. 6), the surface system had begun to occlude as the 500-mb. Low became more closely associated with it, and the slope between them became more nearly vertical. The surface Low that had been over Lake Erie at 1200 GMT, August 25, weakened further and was overshadowed by the east coast development, while aloft it had depressed the flow over the Ohio Valley and presented an unusual flow pattern, with two closed circulations of approximately equal size, only 5° longitude apart.

The surface Low moved northeastward to merge on August 27 with a Low over northern Labrador, as the trough along the east coast filled in a general readjustment of long-wave pattern over the United States, Canada, and the adjacent oceans.

4. MOISTURE AND PRECIPITATION

Figure 7 is a composite chart of 48-hour rainfall, 1200 GMT, August 24 to 1200 GMT, August 26, 1957 and the

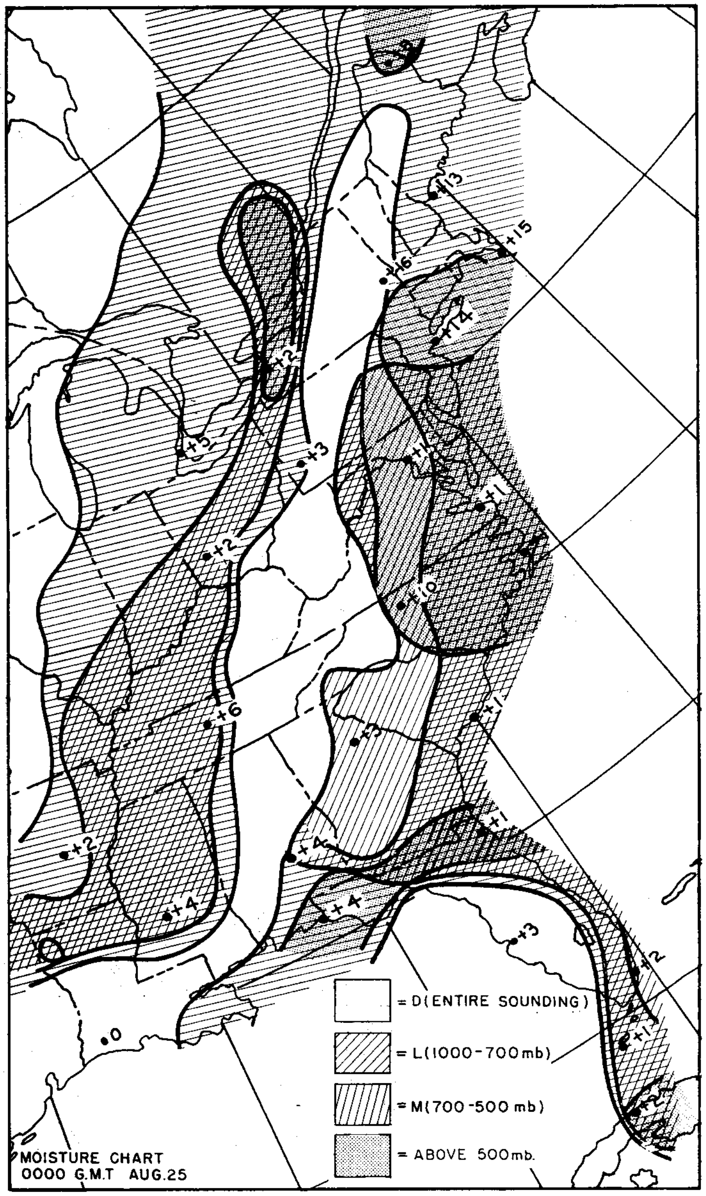

FIGURE 9.—Moisture chart for 0000 GMT, August 25, 1957.

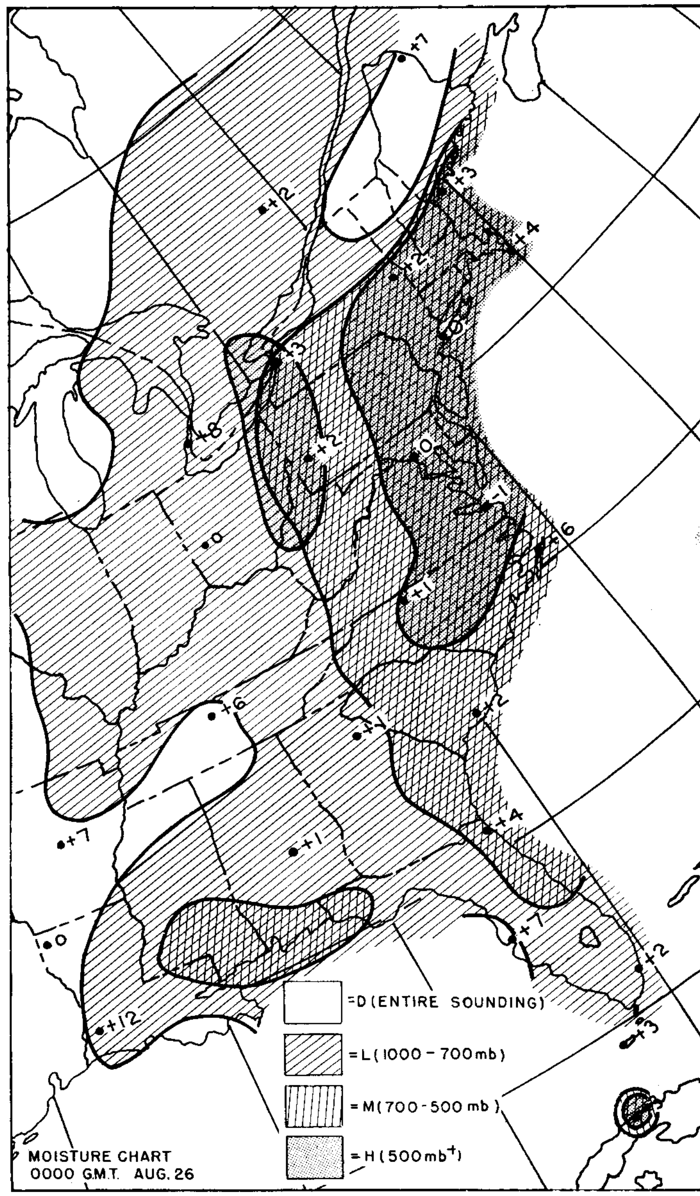

FIGURE 10.—Moisture chart for 0000 GMT, August 26, 1957.

track of 6-hourly positions of the associated surface Low. Development of this precipitation along the Eastern Seaboard has been analyzed only subjectively by means of moisture and streamline charts. An exacting analysis as to cause and effect would be tedious, rather difficult, and too time-consuming for the present purpose. Also, a division of precipitation into its causal classes is not proposed here, except in a general sense into two classes, orographic and non-orographic.

Figures 8, 9, and 10 are charts developed in NAWAC by V. J. Oliver. They represent a subjective approach to portray tropospheric moisture. Stability indices [3] are also plotted on the charts.

The moisture charts, figures 8 and 9, though relative in nature, clearly separate the moisture patterns associated with the east coast Low from the moisture patterns with other systems. Figure 8 shows a wide "dry" belt over the area stretching from Louisiana northeastward to the New England States. The moisture pattern portrayed over the eastern Carolinas and Florida is considered to be part of the system which ultimately produced the drought-relieving rains in the Atlantic Coastal Plain States. Twenty-four hours later (fig. 9) the "dry" belt was still in existence, but not so extensive. Moisture associated with the "system" had spread over the Eastern Seaboard with the greatest depth of moisture extending from central New Jersey southward along the coastal plains to South Carolina. Stability indices had dropped toward zero in the area where greatest moisture depth existed.

Figure 10 depicts the merger of the moisture pattern from the west with that on the east coast as the broad cyclone vorticity field enveloped the whole area east of the Mississippi. The area of greatest moisture depth was, however, still well defined, covering the southern New

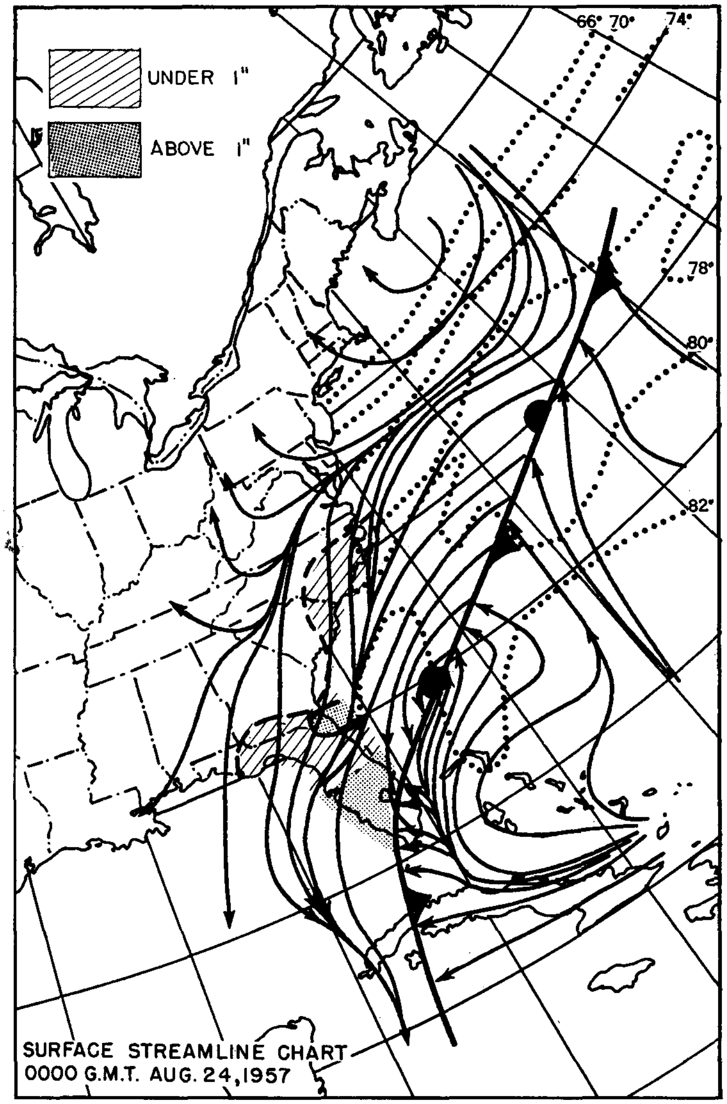

FIGURE 11.—Surface streamlines for 0000 GMT, August 24, 1957 (solid lines with arrow heads). Hatched area indicates .01 to 1.0 inch, stippled area over 1.0 inch of precipitation for 24-hour period ending 1200 GMT, August 24, 1957.

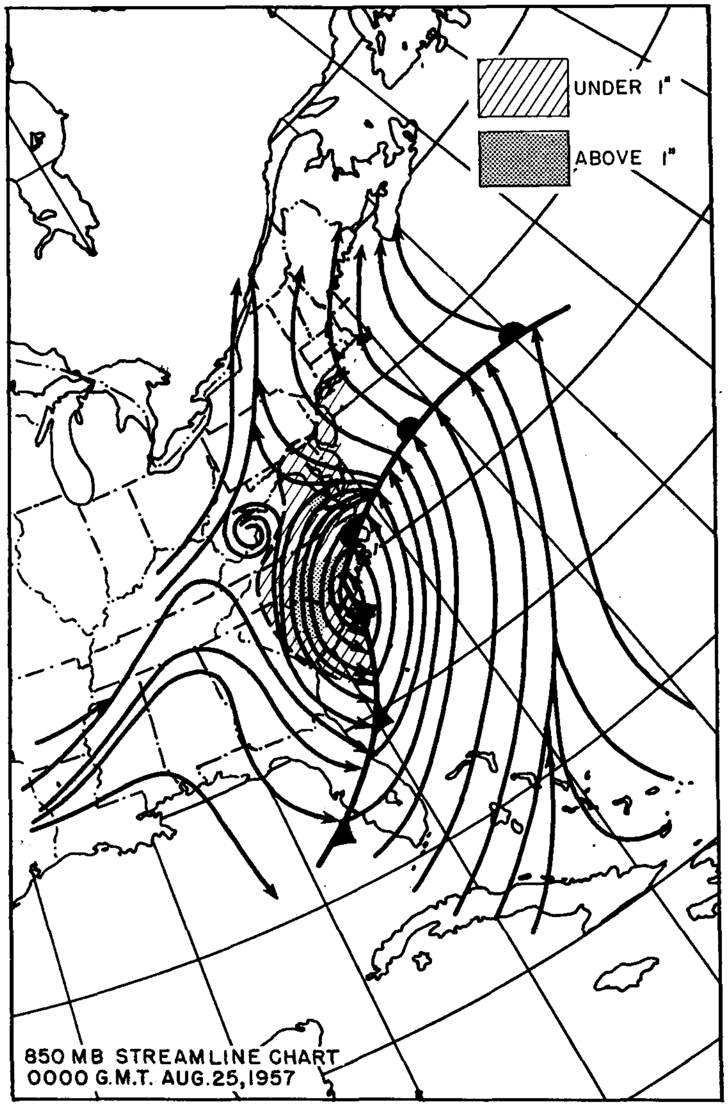

FIGURE 12.—850-mb. streamlines for 0000 GMT, August 25, 1957. Hatched area indicates .01 to 1.0 inch, stippled area over 1.0 inch of precipitation for 24-hour period ending 1200 GMT, August 25, 1957.

England States southward to the Carolinas and bounded on the west by the Appalachian chain. Stability indices from New York City south were close to zero.

A comparison of figures 8, 9, and 10 with the 48-hour precipitation chart, figure 7, shows that the areas of greatest precipitation were blanketed by areas of maximum moisture depth.

5. STREAMLINE ANALYSIS

The streamline analysis was applied to the surface at the beginning of the period (fig. 11), and carried to a higher level (850 mb.) on succeeding charts (figs. 12 and 13). This was done with the desire to depict that moisture came from low-level sources. Each of these analyses is superimposed upon 24-hour precipitation amounts which bracket the indicated time on the streamline charts. The streamlines were determined by the isogonal method which is described in many articles (e. g., [4]) and books on meteorology (viz: Palmer [5], Saucier [6], and Petterssen [7]).

Surface streamlines for 0000 GMT, August 24 are presented in figure 11. Although streamlines represent the instantaneous flow, there are some conclusions that can be deduced. The pattern clearly depicts a main horizontal convergence zone which definitely contributed to vertical motion. This zone, from Cape Hatteras southwestward to Jacksonville, was centered just off shore. There was a secondary zone running parallel to the sea surface isotherms in the vicinity of 38° N. latitude.

Precipitation amounts coincided nicely with the main convergence zone, and it would be reasonable to assume that this convergence played the dominant role, because the front lay considerably to the south of the convergence zone. The precipitation in central Florida was probably

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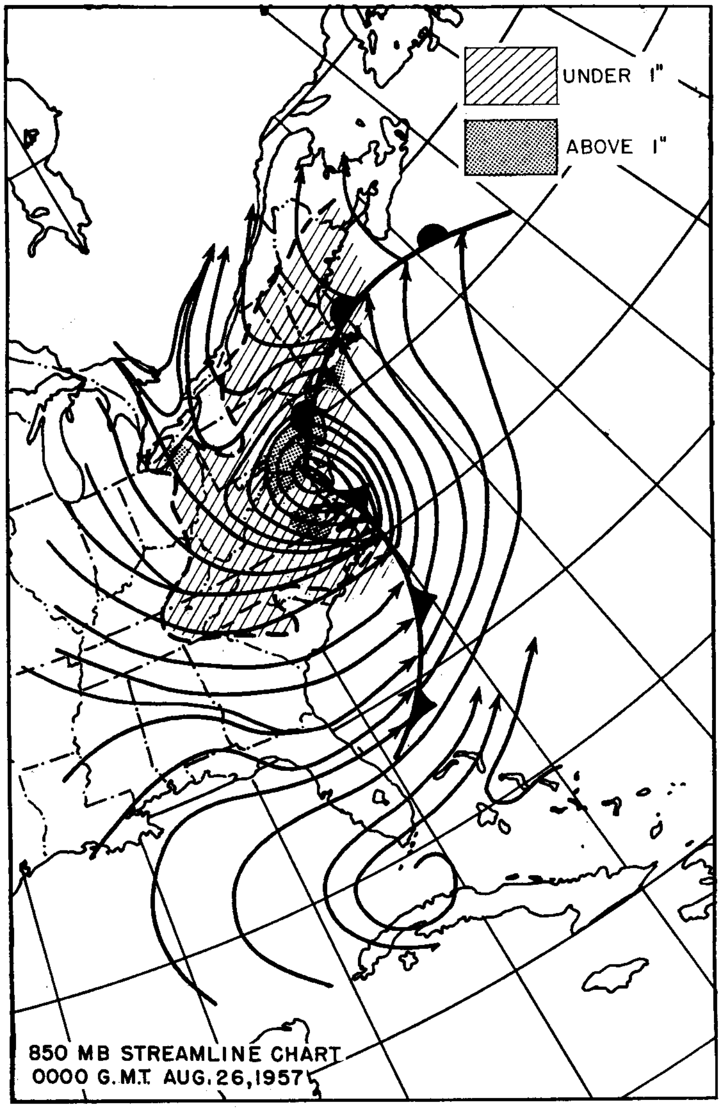

Figure 13.—850-mb. streamlines for 0000 GMT, August 26, 1957. Hatched area indicates .01 to 1.0 inch, stippled area over 1.0 inch of precipitation for 24-hour period ending 1200 GMT, August 26, 1957.

due to lifting of unstable air at the front; this is portrayed by the streamlines which indicate flow perpendicular to the front. See figure 8 for stability indices. The streamline pattern over the northeastern part of the map suggests that air in the Maritime Provinces was moving across the Gulf Stream and being warmed considerably in the lower layers. Thus with low-level turbulent mixing and slight converging flow parallel to the Gulf Stream, air in the lower layers mixed through increasing depth. This air arrived in the area of strong convergence with less stability and increased moisture.

The 850-mb. streamline patterns for 0000 GMT, August 25 and 0000 GMT, August 26, are presented in figures 12 and 13. Figure 12 portrays an area of horizontal convergence in the central Carolinas. This vertical motion zone would be difficult to separate into orographic and non-orographic effects; however, the combined effects led to copious rain in the central parts of North and South Carolina. The belt stretching eastward along the 35° latitude line appears to have been the result of lifting and slight convergence in the frontal zone. The precipitation area as a whole was apparently the net result of lifting by the front or mountains, with horizontal convergence producing vertical motion. The tendency in general was for less stability of the atmosphere. To the west of the rainfall pattern, there was horizontal divergence with evident counterparts in the moisture pattern of 0000 GMT, August 25 (fig. 9).

Figure 13 contains another example of precipitation that can be related to horizontal convergence in an area where the front and mountains did not provide a lifting mechanism. In particular, the rainfall of 1 inch or more in southern Virginia and north-central North Carolina did not result from a frontal and mountain lifting situation. The two heavily shaded precipitation areas to the north, however, do not lend themselves to such an assumption. Again, the net result was created by non-orographic and orographic effects.

In summary, the streamline patterns show horizontal convergence that can be related to heavy rainfall amounts, and furthermore, reasonable assumptions can be made from the streamline patterns as to why precipitation occurred. Trajectories and their relation to available moisture, of course, would have to be considered for more exacting conclusions (cf. [8].)

6. CONCLUDING REMARKS

The factors contributing to or associated with the relief of the drought situation were:

1. Retrogression of east coast trough to an onshore position.
2. The supply of moisture made available by an easterly wave merging with a stationary frontal system prior to wave development. (See [6] for discussion of inverted trough.)
3. Replacement of anticyclonic curvature of surface isobars with general cyclonic pattern from Philadelphia southward to Jacksonville.
4. Vertical distribution of moisture to levels above 500 mb.
5. Topographic and frontal lifting associated with horizontal convergence, and horizontal convergence alone, appear to be related to copious rainfall areas.
6. Stability indices in the neighborhood of zero.

Obviously, the many facets of the subject have not been exhaustively pursued, but it is felt that the above statements are justifiable in the light of material presented.

ACKNOWLEDGMENTS

The writers wish to express their appreciation to the staff members of NAWAC for helpful suggestions and the reviewing of the article, and to the Daily Map Unit of the Weather Bureau for detailed drafting of figures.

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